Management of Neutral Rail Temperature
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Introduction
The management of the neutral temperature of rails has fundamental consequences if not managed well. All railway maintenance involves risks and these can be minimized by modern engineering and management techniques. This presentation identifies those risks with respect to neutral temperature (stress-free temperature) and explains CN’s application of these techniques.

The technique CN is presently using measures the tension in the rail by measuring its stiffness and computing that into the neutral temperature. It is as accurate as strain gauge and cut and is non destructive. It is not affected by residual stresses.

The avoidance of derailment caused by either track buckles or rail breaks is always at the forefront of railway priorities. Maintaining high levels of availability of the track, avoiding unplanned repairs and raising the standards of safety are all important to a railway.

Safety is always paramount for a railway business. Both track buckles and rail breaks can cause a derailment. With derailments there is a risk of loss of life, direct costs of compensation and repair and there is also the serious risk of loss of business as the confidence of the traveling public suffers.

The costs of a derailment include the renewing of the track and that alone is substantial but even the correction of a track buckle or rail break will result not only in the direct material and labour costs but more importantly, loss of availability of the track. The cost of delaying trains is better understood now than ever before. Again, confidence in the ability of the train operator to provide a good service will be affected by poor availability. Even minor train delays such as slow orders have long-term erosive effects on customers.
Review of Track Buckles/Rail Breaks Causes

When the temperature of rail increases it wants to extend its length and when it decreases it wants to shorten. The rail fastenings, the ties and the ballast are all designed to prevent the rail from expanding or contracting so temperature changes result in the rail going into compression when the temperature goes up and into tension when the temperature goes down.

To establish a compromise and to minimize the risk of either breaks or buckles, axial stresses are put into continuously welded rail at installation, rail renewal or repair to counter the effects of temperature changes on the rail from night-time lows in winter to daytime highs in the summer.

If there is excess compression the track will buckle – if there is excess tension the rail will break, probably at a weld, as it is here that the rail is usually at its weakest. Both of these phenomena are dangerous, especially the buckle.

Let’s review causes of track buckles.

Extreme weather conditions
Continuous cycling is believed to affect the neutral temperature of rail over long periods but it has not been cost effective to study exactly how. Extra-ordinary high or low temperatures can permanently change the neutral temperature.

Traffic
It is well known that ballast is a dynamic structure that moves with load and vibration, both elastically and plastically. When trains frequently brake or accelerate on the same section of track it will have the result, over time, of moving the rail ahead in braking and behind in traction. The effect of this is to increase the tension and hence the neutral temperature at one end of a section of track and decrease the neutral
temperature at the other. The rate of change will depend on the type of traffic and the condition of the ballast, tie type, fasteners and their condition and the train and traffic characteristics.

Inclines and declines are similarly affected as trains apply brakes and traction. Likewise, curves can gradually move with vibration and loads, which can result in neutral temperature changes. Again, the rate of change will depend on track conditions and train characteristics.

**Track fastening degradation**
The tension is maintained in the rails by the rail fasteners transferring the loads to the ties and then the ballast. If the fasteners do not apply sufficient toe load or rail anchors are incorrectly fitted or performing badly they will be unable to contain the forces adequately and the neutral temperature will change. Pad, rail seat and insulator wear will have the same effect.

**Ground conditions**
The ground stability can result in changes in the neutral temperature of the rail. Mud spots, pumping and frost heaves will often result in increased rail tension.

**Degrading ballast condition**
Ultimately, it is the ballast or track support that provides the reaction to the tensile and compressive forces in the rail, therefore, if it is in poor condition the neutral temperature will inevitably change away from the ideal.

**Mechanized track maintenance**
The vibrating action of tampers, especially in curves, can result in the curves moving, changing the rail length between the end points thereby changing the neutral temperature. Ballast cleaning and major tie renewal programs have the potential to change the neutral temperature as well.
Poor quality repairs

If rails are re-welded without the correct re-tensioning then the neutral temperature over greater lengths of rail can be adversely affected. Installing new insulated joints or other rail sections without correct de-stressing can also cause problems.

One of the ways to prevent mishaps caused by not knowing the neutral temperatures to destress ahead of a major program to ensure that the rail is at the preferred stress free temperature.

Once the program is completed return to the work area and destress again so that the stress free temperature is at the desired temperature to ensure no buckling.

This is a very costly and time-consuming process. You require:

- Track and welding crews
- Speed swing
- Spike puller
- Spiker
- Anchor applicator
- Anchor remover
- Crew vehicles
- Saws and drills
- Thermite welding equipment

The productivity will be:

- Maybe 1/2 mile per day destressing both sides
- A 40-mile program would take about 80 days.

Using non-destructive rail testing, checks can be made in about 20 minutes per rail with 4 men – no cutting destressing, or welding!

Managing Neutral Temperature

Companies who manage neutral temperature well will reduce neutral temperature induced track failures, thereby increasing availability, reducing safety risks and enhancing business potential. The use of a non-
destructive neutral temperature measurement will allow a much more cost effective way than traditional methods. Good computerized databases will facilitate the long-term study of track behaviour and provide the engineer with the ability to plan his track maintenance more efficiently.

The rail company will be able to maintain better detailed and up-to-date records to demonstrate to its own management, auditing and licensing bodies its diligence in safety management and thereby reduce the opportunities for claims of negligence and litigation.

Overall the adoption of modern measurement techniques will result in the business benefiting from improved operating performance, more effective maintenance investment and greater customer satisfaction and thus competitiveness and profitability.

There are many costs involved in the maintenance of track but it is widely accepted in all engineering maintenance that prevention is more cost effective than repair. Planning when and where any kind of maintenance should be carried out depends on knowing the state of the track and neutral temperature is just like any other track safety characteristic in this respect.

To plan work to manage the neutral temperature can only sensibly be made by measuring the state of the track. Until now this has meant cutting the rail, measuring the stress change and re-stressing the rail. As has already been described, this is costly. Where money is limited this is often one of the first things to be sacrificed.

Historically, many permanent M of W engineers, knowing that the track buckle is the more dangerous and that neutral temperature might well reduce over time (but not necessarily), have understandably erred on the side of caution and set the neutral temperatures even higher than the standard. Despite modern rails being able to bear considerable tensile forces without breaking, the price of this tactic has been a higher frequency of costly and disruptive rail breaks. They may seek to find stronger and higher quality welding techniques but that will not change the thousands of welds already in track.
If the neutral temperature is known then appropriate action can be planned at locations of highest risk, thereby reducing the number of rail breaks yet still avoiding the track buckle.

When new rail is installed either on brand new track or as replacement for worn or damaged rail, the last thing the track engineer wants to do is cut his new rail to check whether he, or his contractor, has done a proper job. It is usually left unchecked and can be a problem just waiting to happen.

Being pro-active and using a non-destructive technique to measure the actual state of the track, will thereby, enable these savings to be made and bring the extra confidence that safety is being professionally managed.

The only way to date to measure the neutral temperature has been to cut the rail and measure the stress change and then re-stress the rail. For an accurate measurement, the fitment of strain gauges is necessary and this requires specialist technicians, preparation and equipment.

Many companies have relied on measuring the relaxation distances of the rail ends but this is known to be at risk of large errors. 15°C errors have been seen, especially where the movements of the ties still attached to the fixed end of the rail are not measured as well. Measuring accurately over long distances is notoriously difficult too.

Non-destructive testing measures the tension in the rail by measuring its stiffness and computing that into the neutral temperature. It is as accurate as strain gauge and cut and is non destructive. It is not affected by residual stresses.
Practical Application Of Non-Destructive Neutral Temperature Measurement

Device.

Materials and Resources:

- Sledgehammers - 4
- Track jacks - 2
- Lining bars - 2
- Paint
- Metal markers

Concrete ties
- T bars - 2
- C bars - 2
- Extra insulators
- Extra clips
- Extra tie pads

Wood ties
- Hydraulic tools
- Claw bars - 2
- Spike mauls - 4
- Tie plugs
- Extra spikes
- Extra anchors

Night Time Equipment

- Power plant and electrical cords
- Hard hat lights (and spare batteries)
- Flood lights

Method Description:

Pre-Lift:
1. Connect the displacement transducer, load cell, power supply and Husky leads to the connector box.
   - Note that the connectors are polarized so they can only be fitted into the correct socket.
2. Check power supply to ensure sufficient power is available for the lift.
3. Ensure that Husky is sufficiently charged.

Lift:
1. Mark center point (lift point) of the site to be assessed.
   - Must be on a tie.
2. Mark the end locations approximately 16.5 metres each side of center point (lift point).
• Ensure that any thermite welds present are located at the outer ends of the center 20 metres.

3. Mark the support block locations at least 10 metres either side of the center point (lift point) to indicate where the support blocks are to be inserted.
   • Must be on a tie.

4. Determine the rail weight and measure the rail height (to nearest mm) using vernier calipers.
   • A 0.5mm error in the measurement of the rail height will produce a nominal error of <0.3C (1F) in the SFT result.

5. Record and note the results.

6. Unclip the 33-metre length of rail.

7. The equipment is then positioned on a tie straddling the rail at the center point (lift point) of the unclipped section.

8. Position track jack beside support block location.


10. Insert support block.

11. Repeat steps 8, 9 and 10 for other support block.
    • Make sure insulators are removed.

12. The rail is then freely suspended between the support blocks.

13. The lifting frame must now be accurately positioned over the rail, at the lift point, using the plumb bob.
    • Position the plumb bob directly over the center of railhead.

14. Fit the rail clamp around the head of the rail and take up the slack in the cable by rotating the adjustable strut.
    • Close the bleed valve on the jack.

15. Set up displacement transducer.
    a) Place the sandbag firmly in the ballast at the side of the tie.
    b) Fit the magnetic clamp on to the head of the rail over the sandbag and switch the magnet on.
    c) Adjust height of displacement transducer on sandbag.

16. Take accurate measurements (to the nearest cm)
a) Center point (lift point) to the support block.

b) Center point (lift point) to the first fastened tie.

c) Repeat for other side of center point (lift point).

17. Record these details.

- A 1 cm error in the measurement of the support block distances will produce a nominal error of 0.1C in the SFT result.
- A 1 cm error in the measurement of the support end span distances will produce a nominal error of <0.05C in the SFT result.

18. All required information to be entered into the Husky is now available.

- The program will ask a series of questions about location, rail type, condition and temperature.
- Use approved thermometer to determine rail temperature.
- Only when all the questions are answered will the program step the operator through the lifting/measuring cycle.

19. Lift the rail by inserting the jack handle and gently (slowly) pumping the jack.

- When a maximum force of the one-ton has been applied, the Husky beeps and instructs the load to be removed.

20. The load is released by opening the bleed valve on the jack.

21. This has completed one lift measurement.

22. At least three lift measurements are made, each taking about one minute to determine the SFT of the rail.

23. After the minimum of three measurements have been made, measure the rail temperature and input into the Husky.

- Select save data and Husky will request the rail temperature.

24. The Husky will now display SFT.

- The SFT and measurement details are recorded electronically.
- However you should document the SFT and measurement details to ensure information is not lost.
Dismantling:
1. Release displacement transducer and tongs and remove from rail.
2. Remove frame from rail.
3. Remove blocks.
4. Lower rail back into rail seats.
5. Re-fasten rail.
   • For maximum efficiency, while the measurements are being taken on one rail, the other rail can be prepared for measurement.
   • As soon as the measurement is complete on one rail the frame can be removed and placed on other rail. First rail can then be re-fastened.

Post Lift:
1. Detailed recorded information, from the Husky, can be downloaded into a laptop computer.
2. Communicate results.

**Application Of Non-Destructive Neutral Temperature Measurement Readings.**

The standards of neutral temperatures are going to depend on the temperature variations in the local climate. The tolerance on this nominal temperature will depend on many issues and we have discussed the technical and quality issues but the category of the track and its traffic type and speed are also going to have a bearing on it. How wide the tolerance is will depend on the judgement of the local track engineer and the standards he can effectively maintain.

When a measurement is taken and a result obtained, a judgement needs to be taken as to whether any remedial action is required. Where the result is in tolerance nothing needs to be done of course. When the result is just outside tolerance, whether above or below, de-stressing or some other remedial action needs to be programmed. Where the result is dangerously outside the tolerance emergency actions need to be taken. This could mean sending out an observer during high temperature until repaired or applying a speed restriction but will mean de-stressing.
The precise values of the tolerance bands can only be defined by the MoW managers.

On some railways the tolerances are as follows:

Target SFT: \( xx^\circF \) (\( yy^\circC \)) +\( ww^\circF \), -\( zz^\circF \)) Any result obtained that is above 15\(^\circF\) this top limit or 15\(^\circF\) below the bottom limit is deemed dangerous.

Consideration should also be given to the acceptable difference in the neutral temperature between one rail and another. Some specify this as a temperature, 5\(^\circF\) is used by some, but it may be a percentage difference.

These standards should be thoroughly reviewed once the state of the track is known and what is achievable economically.

**Results from analysis database.**

**Results of analysis:**
- 507 locations tested
- 156 locations at PRLT or over (31%)
- 185 locations to monitor (36%) (0 – 10 below the PRLT)
- 166 locations to distress (33%) (>10 below the PRLT)

**Savings:**

<table>
<thead>
<tr>
<th>Without non-destructive testing</th>
<th>With non-destructive testing</th>
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<tbody>
<tr>
<td>507 locations</td>
<td>507 locations</td>
</tr>
<tr>
<td>- Each location is approximately 1/4 mile</td>
<td>- 16 locations measured per day</td>
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<tr>
<td>- 127 days for a crew of 12</td>
<td>- 32 days for a crew of 4</td>
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<tr>
<td>- 1524 person days required</td>
<td>- 166 locations requiring destressing</td>
</tr>
<tr>
<td></td>
<td>- 42 days for a crew of 12</td>
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<tr>
<td></td>
<td>- 626 person days required</td>
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</tbody>
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Savings

- 898 person days

CN used non-destructive testing in conjunction with a tamper to correct the neutral temperature through a curve without conventional de-stressing by getting the tamper to move the curve outward to put the tension back into the rail then checking with non-destructive testing. This saved considerable costs.
North Rail versus South Rail Analysis

80 degrees Fahrenheit is the PRLT

The chart shows the difference between the north and south rails.

Surprising how the two rails are generally at different stress free temperatures.

Also of interest is the variation of stress free temperatures.
For the most part everything is below the PRLT

The 4 locations above the PRLT were recently relayed

**Benefits Of Knowing The Neutral Temperature.**

Over the last three years some railways have started to implement this pro-active strategy with more than 6,000 non-destructive neutral temperature measurements taken. Many unnecessary re-stressing operations have been avoided, high-risk situations corrected before serious incidents have occurred and new, comprehensive records have been created. Valuable lessons have been learned about the state of the track and questions raised about standards and procedures.

Some non-destructive testing users have taken as many as 1000 measurements in a matter of weeks allowing them to really understand the state of their track. This has allowed them to correct those sites where there are serious faults and plan the correction of less crucial ones when they can have access to the track or when other maintenance is required at the same location.

Some areas have found as many as 30% of the sites measured have a problem. These can be significant differences of stress from one rail to the other in the same track and only 400m apart. This should be of no surprise if track, ballast and fasteners are all in good condition, as they will contain the variations in stress. These variations have always been there – we have just not seen it before.

Canadian National Railways is studying the effect on neutral temperature of ballast cleaning machines and other mechanical track maintenance procedures. Dallas Area Rapid Transit is checking brand new track before commissioning and are finding problems with previous stressing techniques. Finland and Italy are also just starting, as are Union Pacific and Burlington Northern-Santa Fe in the USA. Other railway companies in Europe are in the final stages of evaluating the strategy and many are expected to commit.

Stressing techniques have shown to be flawed in their accuracy. On the Dallas Area Rapid Transit’s new track, greater than 5% variation has been found between one rail and the other.
On more than one railway safety margins and tolerances on the neutral temperature standards are being challenged.

We now have a means to research the behaviour of track that would have been totally impractical requiring cutting of the rail. We now have the opportunity to study the effects of time, traffic, maintenance, weather, and track component condition to better understand the long-term behaviour and risks.

We can now challenge the standards, techniques and procedures for the establishment of the correct neutral temperature. All it needs is the building of a measurements database and there is the opportunity to undertake specific research without damage to track.

In the long term, track engineers will be able to more accurately correlate the actual neutral temperatures of their track, the rates at which the neutral temperatures have changed, the circumstances that made them change with the frequency of failures and thereby refine their neutral temperature standards and tolerances to minimize these risks.

Let us not forget that there was much research and development done in the 1950s that could be brought up to date by validation with a non-destructive measuring technique.

The adoption of a more rigorous, pro-active, neutral temperature management regime is now possible because of the availability of an accurate, non-destructive measurement method.

This strategy can bring real benefits of reduced dangerous incidents, increased track availability, improved understanding of the track behaviour, better maintenance planning, reduced risk of litigation and better maintenance expenditure. These are all powerful motivators in making the railway more competitive and cost effective.

End